JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES
VOL. 11 NOVEMBER 19, 1921 NO. 19

MATHEMATICS.—*On the correlation between any two functions and its application to the general case of spurious correlation.*[1] LOWELL J. REED, Johns Hopkins University. (Communicated by Raymond Pearl.)

In problems where correlation methods are employed it is often necessary to determine the coefficient of correlation between one of the measured variables and some function of the others. In certain cases we need to go still further and determine the correlation between two different functions of the measured variables. Such cases arise where two different index numbers are correlated with each other or when an index number is correlated with one of the measured variables. In all problems of this type the coefficient of correlation may be found by computing the value of the function in question at each position for which the values of the variables themselves are known and then finding the correlation coefficient in the usual way. In a great many cases however there would be a considerable saving of labor if this coefficient could be determined directly from the means, standard deviations, and first order correlation coefficients of the variables themselves. The following general equation has been derived to accomplish this and it should prove to be of use in problems of the type outlined above. The proof of the formula is too long to be given in the present paper, but will be published later, together with additional illustrations of its application.

Let $x_1, x_2, \ldots\ldots x_n$ be a set of n variables,
and $x_1', x_2', \ldots\ldots x_k'$ be a second set of k variables.
Let $m_1, m_2, \ldots\ldots m_n$ be the means of the variables of the first set,
$\sigma_1, \sigma_2, \ldots\ldots \sigma_n$ be their standard deviations,
and $r_{x_1x_2}, r_{x_1x_3} \ldots\ldots r_{x_{n-1}x_n}$ be the coefficients of correlation between these variables taken in pairs.

[1] Papers from the Department of Biometry and Vital Statistics, School of Hygiene, Johns Hopkins University, No. 38. Received October 18, 1921.

The same notation will be used for the means, standard deviations and coefficients of correlation of the primed variables.

Now let $y = f(x_1, x_2, \ldots\ldots x_n)$

and $z = f(x'_1, x'_2, \ldots\ldots x'_k)$

represent any two analytic functions of these two sets of variables. Then the correlation between these two functions is measured by

$$r_{yz} = \frac{\sum_{\alpha=1}^{n}\sum_{\beta=1}^{k} f_\alpha F_\beta r_{x_\alpha x'_\beta}\sigma_\alpha\sigma_\beta}{\sqrt{\left[\sum_{\alpha=1}^{n}\sum_{\beta=1}^{n} f_\alpha f_\beta r_{x_\alpha x_\beta}\sigma_\alpha\sigma_\beta\right]\left[\sum_{\alpha=1}^{k}\sum_{\beta=1}^{k} F_\alpha F_\beta r_{x'_\alpha x'_\beta}\sigma'_\alpha\sigma'_\beta\right]}} \quad (1)$$

in which

$$f_\alpha = \frac{\partial f(m_1, m_2, \ldots\ldots m_n)}{\partial m_\alpha}$$

and

$$F_\beta = \frac{\partial F(m'_1, m'_2, \ldots\ldots m'_k)}{\partial m'_\beta}.$$

The derivation of equation (1) yielded as a by-product the expressions for the mean and standard deviation of any function of a set of variables in terms of the means, standard deviations and first order coefficients of correlation of the variables themselves.[2] These formulae are

(a) for the mean value of $y = f(x_1, x_2, \ldots\ldots x_n)$,

$$m_y = f + \tfrac{1}{2}\sum_{\alpha=1}^{n}\sum_{\beta=1}^{n} f_{\alpha\beta} r_{x_\alpha x_\beta}\sigma_\alpha\sigma_\beta \quad (2)$$

where $f = f(m_1, m_2, \ldots\ldots m_n)$

and $f_{\alpha\beta} = \dfrac{\partial^2 f(m_1, m_2, \ldots\ldots m_n)}{\partial m_\alpha \partial m_\beta}$

(b) for the standard deviation of $y = f(x_1, x_2, \ldots\ldots x_n)$,

$$\sigma_y = \sqrt{\sum_{\alpha=1}^{n}\sum_{\beta=1}^{n} f_\alpha f_\beta r_{x_\alpha x_\beta}\sigma_\alpha\sigma_\beta} \quad (3)$$

[2] For another derivation of equations (2) and (3) see E. CZUBER, *Über Funktionen von Variablen zwischen welchen Korrelationen bestehen.* Metron 1, No. 1, July, 1920.

Equations (1), (2) and (3) furnish a complete set of formulae for the determination of the means, standard deviations, and coefficient of correlation of any two functions of two sets of variables in terms of the means, standard deviations, and coefficients of correlation of the variables themselves.

It should be noted that, in the derivation of these formulae, all terms of the third or higher orders in the variables $\frac{\sigma_1}{m_1}, \frac{\sigma_2}{m_2}$, etc., were disregarded. Therefore in a practical problem when the standard deviation is large as compared with the mean the formula might not give a sufficiently close approximation to the true value of the correlation coefficient. In the majority of cases, however, the ratio of the standard deviation to the mean is a sufficiently small decimal so that disregarding its powers higher than the second can have no appreciable effect on the result.

To illustrate the use of equation (1) we may first apply it to the case of the correlation between ratios. Let the variables be x_1, x_2 and x_1', x_2' and the ratios be $y = \frac{x_1}{x_2}$ and $z = \frac{x_1'}{x_2'}$.

Then $$f_1 = \frac{1}{m_2}, \; f_2 = -\frac{m_1}{m_2^2}$$

$$F_1 = \frac{1}{m_2'}, F_2 = -\frac{m_1'}{m_2'^2}.$$

Substituting these values in (1) and replacing $\frac{\sigma_1}{m_1}$ by v_1, $\frac{\sigma_2}{m_2}$ by v_2, etc., we have

$$r_{yz} = \frac{r_{x_1x_1'}v_1v_1 - r_{x_1x_2'}v_1v_2 - r_{x_2x_1'}v_2v_1' + r_{x_2x_2'}v_2v_2'}{\sqrt{(v_1^2 + v_2^2 - 2r_{x_1x_2}v_1v_2)\,(v_1'^2 + v_2'^2 - 2r_{x_1'x_2'}v_1'v_2')}}. \quad (4)$$

This is Pearson's[3] well known formula for the coefficient of correlation of two indices or ratios. Formulae for the means and standard deviations of y and z can be obtained from equations (2) and (3).

They are $m = \frac{m_1}{m_2}\,[1 + v_2^2 - r_{x_1x_2}v_1v_2]$

and $\sigma_y = \frac{m_2}{m_1}\sqrt{v_1^2 + v_2^2 - 2r_{x_1x_2}v_1v_2}$.

[3] PEARSON, K. *On a form of spurious correlation which may arise when indices are used in the measurement of organs.* Proc. Roy. Soc., London **60**. 1896.

As a second illustration let us consider the correlation between products of the variables.

Let $y = x_1x_2$ and $z = x_1'x_2'$.

Then from (1) we have

$$r_{yz} = \frac{r_{x_1x_1'}v_1v_1' + r_{x_2x_1'}v_2v_1' + r_{x_1x_2'}v_1v_2' + r_{x_2x_2'}v_2v_2'}{\sqrt{(v_1^2 + v_2^2 + 2r_{x_1x_2}v_1v_2)(v_1'^2 + v_2'^2 + 2r_{x_1'x_2'}v_1'v_2')}}. \quad (5)$$

The mean and standard deviation, derived from equations (2) and (3), are given by

$$m_y = m_1m_2[1 + r_{x_1x_2}v_1v_2]$$

and

$$\sigma_y = m_1m_2\sqrt{v_1^2 + v_2^2 + 2r_{x_1x_2}v_1v_2}.$$

If we consider x_2' to be constant we have a special case of formula (5) of considerable importance; that is, the case of the correlation between the product of two variables, $y = x_1x_2$, and some third variable $z = x_1'$.

For this case

$$r_{yz} = \frac{r_{x_1x_1'}v_1 + r_{x_2x_1'}v_2}{\sqrt{v_1^2 + v_2^2 + 2r_{x_1x_2}v_1v_2}}. \quad (6)$$

Formulae (5) and (6) will be found useful in those cases in which the product of two measurable linear functions is used as an index number for a surface that cannot be directly measured, as is the case for instance in dealing with the surface of the human body.

The problem of finding the coefficient of correlation between some function of a set of variables and some other measured variable is so common that it is advisable to consider the form taken by equation (1) in this case. We would have

$$y = f(x_1, x_2, \ldots\ldots\ldots x_n) \text{ and } z = F(x_1') = x_1'.$$

Then

$$r_{yz} = \frac{\sum_{\alpha=1}^{n} f_\alpha r_{x_\alpha x_1'}\sigma_\alpha}{\sqrt{\sum_{\alpha=1}^{n}\sum_{\beta=1}^{n} f_\alpha f_\beta r_{x_\alpha}\sigma_\alpha\sigma_\beta}}. \quad (7)$$

It should be noted that the standard deviation of the variable x_1' does not enter this equation directly, the only factor involving x_1' being the correlation coefficient $r_{x_\alpha x_1'}$. Equation (6) which was derived as a special case of formula (5) might have been obtained directly from (7).

SPURIOUS CORRELATION

Attention was first called to the subject of spurious correlation in a paper by Pearson[4] where he considered the case of the spurious correlation between two ratios of the form $\frac{x_1}{x_3}$ and $\frac{x_2}{x_3}$. Pearson showed that although x_1, x_2, and x_3 were uncorrelated variables there would be correlation between the two ratios $\frac{x_1}{x_3}$ and $\frac{x_2}{x_3}$, this correlation arising from the fact that x_3 is common to the two indices. Since this correlation exists where there is no correlation between x_1, x_2 and x_3 he gave it the name of *spurious correlation*. The arguments used by Pearson in connection with the spurious correlation between ratios will hold in the case of correlation between any two functions, and a general definition of spurious correlation might be given as follows.

Though no correlation exists between any two of a set of variables there will still exist correlation between any two functions of these variables whenever these two functions have any of the variables in common. The correlation existing under these conditions will be called *spurious correlation.*

A general formula for spurious correlation may be derived directly from equation (1). Using, as before, $y = f(x_1, x_2, \ldots\ldots x_n)$ and $z = F(x_1', x_2' \ldots\ldots x_{k'})$ we shall have spurious correlation only when some of the variables $x_1, x_2, \ldots\ldots x_n$ are identical with some of the variables $x_1', x_2' \ldots\ldots x_{k'}$.

Let
$$x_1 = x_1'$$
$$x_2 = x_2'$$
$$(\quad \cdots \quad)$$
$$x_h = x_h' \quad \text{where } h \leqq k \quad \text{and } h \leqq n.$$

Then, from the definition of spurious correlation, $r_{x_\alpha x_\beta} = 0$ except for the cases where $\alpha = \beta \leqq h$ in which event $r_{x_\alpha x_\beta} = 1$.

[4] *Op. cit.*

Thus we shall have

$$\rho_{yz} = \frac{\sum_{\alpha=1}^{h} f_\alpha F_\alpha \sigma_\alpha^2}{\sqrt{\left[\sum_{\alpha=1}^{n} f_\alpha^2 \sigma_\alpha^2\right]\left[\sum_{\alpha=1}^{k} F_\alpha^2 \sigma_\alpha'^2\right]}} \tag{8}$$

where ρ is used to denote spurious correlation.

All of the special cases considered under equation (1) will exhibit one or more forms of spurious correlation.

For example, when $y = \frac{x_1}{x_2}$ and $z = \frac{x_1'}{x_2'}$ we may have three different cases of spurious correlation:

(a) when the fractions have the same denominator, *i. e.*, $x_2 = x_2'$
(b) when the denominator of one is the same as the numerator of the other, *i. e.*, $x_2 = x_1'$
(c) when the fractions have common numerators, *i. e.*, $x_1 = x_1'$.
The formulae for the spurious correlation in these three cases are

(a) $$\rho_{yz} = \frac{v_2^2}{\sqrt{(v_1^2 + v_2^2)\,(v_1'^2 + v_2^2)}} \tag{9}$$

(b) $$\rho_{yz} = \frac{-v_2^2}{\sqrt{(v_1^2 + v_2^2)\,(v_2^2 + v_2'^2)}} \tag{10}$$

(c) $$\rho_{yz} = \frac{v_1^2}{\sqrt{(v_1^2 + v_2^2)\,(v_1^2 + v_2'^2)}}. \tag{11}$$

Of these three cases the first one is the one which usually arises in practice.

When the functions considered are products they may have a common factor so that $y = x_1x_2$ and $z = x_1'x_2$.
Then

$$\rho_{yz} = \frac{v_2^2}{\sqrt{(v_1^2 + v_2^2)\,(v_1'^2 + v_2^2)}}. \tag{12}$$

The foregoing illustrations show a few of the equations for specific cases of spurious correlation that can be derived from the general formula. Similar expressions may be obtained from equation (8) for the spurious correlation between any two functions. The value of the spurious correlation involved should always be considered when drawing conclusions from the coefficient of correlation of any two index numbers regardless of their functional form.

PHYSICS.—*The discontinuity of resistance preceding supraconductivity.*[1] P. W. BRIDGMAN, Jefferson Physical Laboratory, Harvard University.

The phenomenon of supraconductivity has to the present time been found in mercury, tin, thallium, and lead.[2] The resistance of the first three of these metals changes discontinuously by a factor of the order of 10^8 at a definite critical temperature. This temperature is 4.2° K. for Hg, 3.78° for Sn, and 2.3° for Tl. The probability is that the resistance of lead decreases discontinuously in the same way on entering the supraconducting state, but the temperature has not yet been definitely measured because it is in the range between 4.3° and 20° which cannot as yet be controlled by a suitable cryostat. Onnes estimates that the temperature of discontinuity of lead is about 6° K.

The discontinuous change of resistance has often been supposed to be in some way intimately connected with the supraconducting state. For instance, J. J. Thomson has a theory accounting for the sudden disappearance of resistance.[3] Now if such a phenomenon of discontinuity occurred at an ordinary temperature, one would almost certainly look for a polymorphic change as the cause of the discontinuity. The thesis which I wish to support in this paper is that the discontinuous change of resistance on entering the supraconducting state is also a mark of a polymorphic change, and that discontinuity and supraconductivity are not as intimately related as sometimes supposed, but are due to quite distinct mechanisms.

According to this view, the normal condition in an individual crystal grain of any metal at very low temperatures is supraconductivity. Any ordinary metal is an aggregate of crystal grains in ran-

[1] Received October 12, 1921.

[2] C. A. CROMMELIN. Phys. Zeitschr. **21**: 274, 300, and 331. 1920.

[3] J. J. THOMSON. Phil. Mag. **30**: 192–202. 1915.

dom orientation with respect to each other. Between the crystalline grains there are localities in which the atoms are not regularly arranged, but the metal is more or less amorphous in character, and in these localities there is a residual resistance that persists to absolute zero. The curve of resistance against temperature of such a metal becomes asymptotic at absolute zero to a low but finite resistance. Suppose, however, the metal is one having a polymorphic transition in the region of low temperatures. Normally the growth of the polymorphic form will start from a single nucleus, so that after the transition the wire will consist of a single crystalline grain without amorphous regions. On raising the temperature again beyond the transition point the wire recovers its original crystalline structure and its original resistance. The recovery of the original structure is of course evidence of some sort of residual nuclear structure in the low-temperature modification. This appears at first sight not what one would expect, but it is exactly what is found in the transition of ordinary polymorphs at higher temperatures.

Apart from its intrinsic probability and the fact that this view does not need to invoke a new mechanism to explain the discontinuity, there is considerable evidence in its favor. In the first place the original belief that supraconductivity was in some way connected with the purity of the metal, and that only those metals would show that it could be obtained in a state of extreme purity, has not turned out to be true. It has been found that amalgams show the effect, and that gold, which has been obtained in a higher state of purity than lead or tin, does not show the effect.

The appearance of supraconductivity is to a certain extent capricious, and occasionally samples are prepared which for some unknown reason do not become supraconducting. This is to be explained by some accident of structure or handling which caused the growth of the polymorphic form to start from more than one nuclear center, so that regions of separation between the different grains persist beyond the transition point.

The temperature of the discontinuity of resistance is known to be depressed when the current in the conductor is increased, and also when the conductor is placed in a magnetic field. Silsbee[4] has shown in this JOURNAL that the probability is high that the phenomena are not unrelated, but that the threshold value of the current is that at which the magnetic field within the wire due to the current itself

[4] F. B. SILSBEE. This JOURNAL 6: 597–602. 1916.

reaches the threshold value. It is sufficient to explain, therefore, the effect of the magnetic field on the temperature of discontinuity. I show in the following that the temperature of a polymorphic transition is altered by a magnetic field, so that again we do not have to invoke any unusual or new connection between the conduction mechanism at low temperatures and the magnetic field in order to explain the facts. In addition to the effect on the temperature of discontinuity, the magnetic field exerts a large effect on the resistance above the transition point; we are not here concerned with this effect, but merely with the relation between the field and the discontinuity (or polymorphic transition).

Since it requires energy to magnetize a body, a simple thermodynamic argument is capable of finding the effect of a magnetic field on a transition temperature. The argument runs precisely like that used in deducing Clapeyron's equation for the connection between an increment of pressure and the change in the temperature of a transition point. The classical Clapeyron's equation is

$$\frac{d\tau}{\tau} = \frac{(v_2 - v_1)dp}{\lambda}$$

This is obtained by a direct application of the second law of thermodynamics to a cycle consisting of a transition from phase (1) to phase (2) at temperature τ and pressure p, transfer of the substance to temperature $\tau + d\tau$ and pressure $p + dp$, transition here in the reverse direction from phase (2) to phase (1), and transfer of the substance back to the initial temperature and pressure. In the equation above, λ is the latent heat absorbed when phase (1) passes to (2), and $(v_2 - v_1)dp$ is the work received by the external forces during the cycle.

The analysis is precisely similar in the case of a magnetic field except that the work done by the external forces, which in the previous case was work done by the external pressure, now becomes work done by the magnetic forces. The cycle consists of a transition from phase (1) to (2) at temperature τ and magnetic field H, transfer of the substance to temperature $\tau + d\tau$ and field $H + dH$, transition in the reverse direction from (2) to (1), and transfer of the substance back to the initial temperature and field. In Clapeyron's equation as written above we merely have to replace $(v_2 - v_1)dp$ by the work done during the cycle on the magnetic forces. Now the work done by the magnetic forces during a change of magnetization is HdI.

During the first transition H remains constant, but I changes from k_1H to k_2H. Hence the total work during the transition is $H^2(k_2 - k_1)$. During the transfer from τ and H to $\tau + d\tau$ and $H + dH$, the susceptibility remains constant, but H changes by dH. The work during this stage is k_2HdH. Similar expressions give the work during the other two stages of the cycle. The total work of the cycle is $HdH(k_1 - k_2)$, and the equation for which we are searching is therefore

$$\frac{d\tau}{\tau} = \frac{(k_2 - k_1)HdH}{\lambda}.$$

Under ordinary conditions the change of transition temperature in a magnetic field is very small, but at low temperatures the effect may become large. For the energy content of a body decreases as the fourth power of the absolute temperature, so that λ varies as τ^4, and if Curie's law is true, the susceptibility varies inversely as the temperature, so that, other things being equal, the change of transition temperature in a magnetic field varies inversely as the fourth power of the temperature.

The formula as given above applies to an infinitesimal temperature range. When approaching zero, the actual change of temperature in a finite field must be found by an integration of this equation. If we make the assumptions of the last paragraph, we have

$$\tau^4 d\tau = \text{Const.}\, HdH$$

which on integration goes into

$$\tau^5 - \tau_0^5 = \text{Const.}\, H^2.$$

The data by which this equation may be checked are meager, but they are at least consistent with it. In default of measurements of energy content and susceptibility at low temperatures, the equation could be checked from measurements of the normal temperature of discontinuity and the corresponding temperature in two different magnetic fields. The only metal for which Onnes gives the effect of two different magnetic fields on the temperature of discontinuity is lead, and we have already mentioned that the normal temperature for this substance has not been accurately measured. However it is interesting to show that the data for lead are at least consistent with this point of view. From a diagram given by Onnes[5] (he does not publish the values numerically) I deduce that the temperature of discontinuity in a field $H = 930$ is 4.25°, and in a field 1130 is

[5] H. KAMERLINGH ONNES. Proc. Amst. Acad. Sci. 16: (2) 991. 1914.

2.0°. The rapid fall of temperature with comparatively slow rise of field is what we would expect from the equation. Now if we assume that the equation above is true, and find τ_0 by substituting the known values, we shall get 5.3° for the normal transition temperature, against the estimate of Onnes of 6°. This I believe must be considered to be within possible experimental error.

Another detail of the behavior of the magnetic field is also consistent with this view. Onnes found that at a fixed temperature the threshold value of the field was slightly higher for a field parallel to the wire than for one transverse to it. The probable reason is that when the field is transverse there are regions inside the wire itself where the circumferential field due to the current in the wire is in the same direction as the external applied field, whereas this is not the case for the longitudinal field. Hence in the transverse case the maximum field is greater than the measured field, and the applied field does not have to be raised so high in order that the critical value may be reached.

The temperature of transition of the four metals hitherto measured is depressed in a magnetic field. This means that the phase stable at the lower temperature has the greater susceptibility. It does not appear to me whether there is any reason why this should be universally true, or whether it is possible that there may be substances whose temperature of discontinuity is raised in a magnetic field.

This view of the discontinuity as due to a polymorphic change ought to be capable of independent experimental verification. It should be possible to detect discontinuous changes in other physical properties—so far as I know the search has not been made for these—and it may be possible to realize supraconductivity in metals which do not normally show it, by recrystallizing a wire at higher temperatures, as can now be done for tungsten, before subjecting it to low temperatures.

PETROLOGY.—*The granites of Washington, D. C.*[1] HENRY S. WASHINGTON, Geophysical Laboratory, Carnegie Institution of Washington.

The granites of the District of Columbia and its vicinity belong to the great belt of Archean intrusives (mostly granite with smaller

[1] Received October 21, 1921. Presented before the Geological Society of Washington October 26, 1921.

amounts of diorite, gabbro, diabase, and pyroxenite) that extends along the Piedmont Plateau from Georgia through Maryland, and northward into New England. The granites and other igneous rocks of the District have been little studied; or, at least, little detailed information regarding them has been published. Merrill,[2] Williams,[3] and Keith[4] give us but very summary descriptions, although Keyes[5] describes in great detail the related and closely similar granites of central Maryland. Only one analysis, and that one incomplete, of a fresh Washington granite has been published, together with one of a weathered granite.

Mr. L. H. Adams of this Laboratory selected a specimen of the Tilden Street granite for his study of the compressibility of rocks. I made a chemical analysis of this for him, and was thus led to analyze other specimens from the District. The results of these analyses, accompanied by brief petrographic descriptions, are given in this paper, in the hope that they may be of use to some geologist who in the future will study the region thoroughly. No attempt is made here to discuss, even summarily, the structural geology or the relations of the granites to the other igneous rocks or to the intruded gneisses (fig. 1).

Types.—Keith refers the granite of the Washington Folio to three classes: granite-gneiss, granitic dikes in the gneiss, and intrusive granite. All the specimens described in the present paper are of intrusive granite, so far as has been ascertained, although some of them are markedly foliated or gneissoid. Whether some of these last belong in reality to the granite-gneiss or to the Carolina gneiss must be left to the structural investigator.

The granites studied may be referred to two fairly distinct types, biotite granite and muscovite-biotite granite. Although all the specimens of granite show evidence of crushing and other results of pressure, non-foliated or slightly foliated forms of each occur, and from these they pass into intensely foliated, gneissoid forms. It would appear that the two extremes of the types are quite distinct chemically, the type with muscovite being considerably higher in silica than the type with biotite alone, but that they are connected by intermediate forms.

[2] G. P. MERRILL. Bull. Geol. Soc. Amer. **6**: 321. 1895. *Rocks, rock-weathering and soils*, p. 206. 1897.

[3] G. H. WILLIAMS. U. S. Geol. Survey Ann. Rep. **15**: 657–684. 1895.

[4] A. KEITH. U. S. Geol. Survey Folio 70 (Washington Folio). 1901.

[5] C. R. KEYES. U. S. Geol. Survey Ann. Rep **15**: 685–737. 1895.

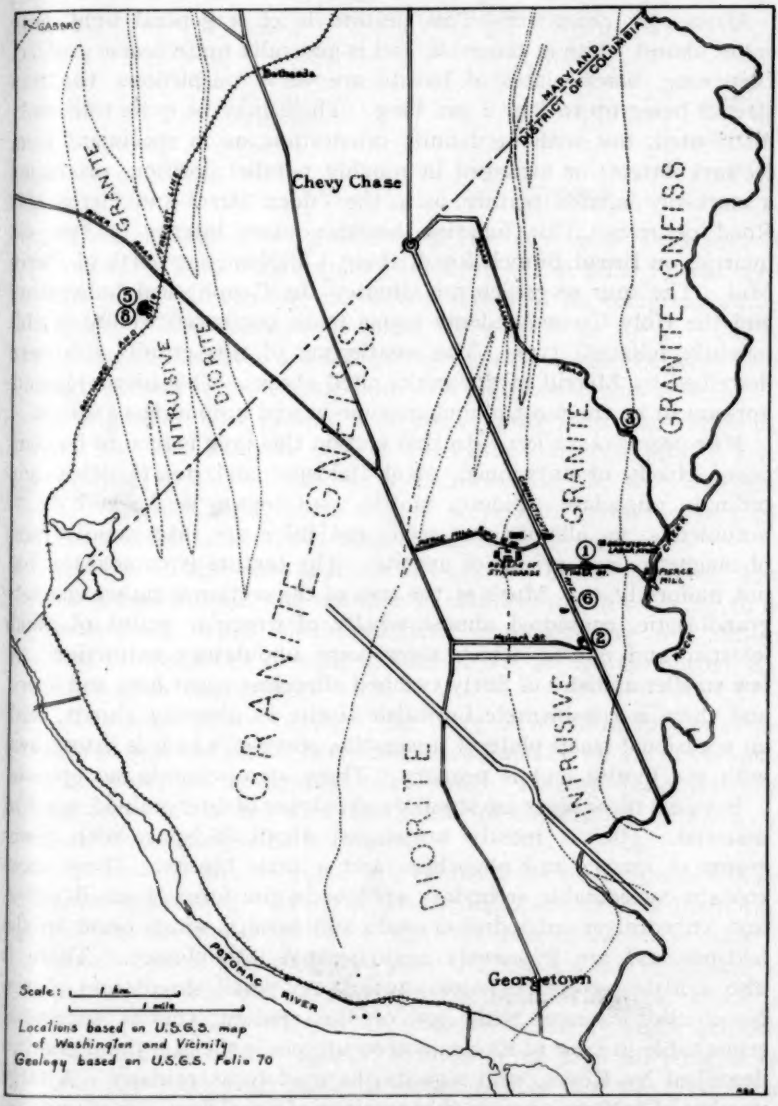

Fig. 1. Geological map showing location of analyzed specimens of granite.

BIOTITE GRANITE (TILDEN STREET TYPE)

Megascopic characters.—This granite is of a general light gray color, almost white in the mass, and is generally quite coarse grained. Glistening, black plates of biotite are very conspicuous, the thin streaks being up to 1 or 2 cm. long. These may be quite uniformly distributed, but without definite orientation, as in specimens from Newark Street; or arranged in roughly parallel position, producing a markedly foliated texture, as in the Tilden Street and Pierce Mill Road quarries. This foliation becomes more intense in two old quarries on Broad Branch Road, about 1.3 kilometers north of Pierce Mill. The spur on which are situated the Geophysical Laboratory and the Holy Cross Academy seems to be composed wholly of this (slightly foliated) type. The weathering of this granite has been described by Merrill in the works cited above. This biotite granite appears to be the most abundant type in and around the District.

Microscopic characters.—In thin section this type is seen to be composed chiefly of untwinned, alkali feldspar and quartz, with subordinate oligoclase, epidote, biotite, and muscovite. There is no hornblende, no allanite was seen, and there are rare, small grains of magnetite and prisms of apatite. The texture is cataclastic, but not uniformly so. Much of the area of the section is rather coarsely granoblastic, composed almost wholly of irregular grains of alkali feldspar and quartz, which show some undulatory extinction. A few smaller anhedra of finely twinned oligoclase occur here and there, and there is considerable brownish biotite in irregular shreds, with an occasional small plate of muscovite, some of which is intergrown with the biotite and is primary. These areas contain no epidote.

Between these areas are streaks and patches of finer grained, crushed material. This is mostly untwinned alkali feldspar, with fewer grains of quartz and oligoclase, and a little biotite. These areas contain considerable secondary epidote in the form of small, colorless, euhedral or subhedral crystals and prisms, which occur in the feldspar and are frequently agglomerated into clusters. There is also a little secondary muscovite in very small shreds and plates. No allanite was seen with any of the epidote; this is somewhat remarkable in view of its common occurrence in the Maryland granites described by Keyes, who regards the epidote as primary. A large number of traverses across thin sections of the Tilden Street granite, including areas of both kinds of material, gave the mode shown in table 1, in volumes and weights.

TABLE 1. MODE OF BIOTITE GRANITE FROM TILDEN STREET

	Vol.	Wt.
Quartz	29	29.0
Orthoclase	53	51.0
Oligoclase	4	4.0
Biotite	7	7.6
Muscovite	1	1.0
Epidote	6	7.4
	100	100.0

Composition.—Two specimens of this type were analysed. That from the Tilden Street quarry (analysis (1) in table 2) was used by Mr. L. H. Adams for the determination of its compressibility and density. The density was found to be 2.739 at 30° C. The other (2), was taken from a small quarry recently opened between Newark and Ordway Streets near and west of Connecticut Avenue. This is somewhat finer grained and less foliated than the Tilden Street granite. An analysis (3), of the Broad Branch biotite granite, described by Merrill, and one of the Rowlandsville, Maryland, granite (4), described by Williams and by Keyes, are given for comparison. (See first four analyses of table 2, and map, figure 1.)

Norm.—These are analyses of rather "basic" granites, low in silica, high in lime, and not high in alkalies, with a tendency to dominant soda. Their chemico-mineral characters are well shown in their norms, given in table 3, that of No. (3) being omitted, as the analysis is incomplete.

The resemblance between the three is manifest in the symbols. All are near the border between classes I and II, all are in the quardofelic order and in the alkalicalcic rang. The two from Washington are sodipotassic, but near the border of the dosodic subrang, while that of Rowlandsville is dosodic.

Comparing the norm of No. (1) with its mode, certain discrepancies are evident. Much of the abundant anorthite of the norm enters into the modal epidote, along with some of the ferric oxide. As epidote has an excess of CaO over $(Al,Fe)_2O_3$ this will liberate some alumina for the biotite, in which the normative hypersthene finds place. The alkali feldspar is evidently a highly sodic orthoclase. From the two sets of figures, however, even after all possible readjustments have been made, it would appear that the sections used for the Rosiwal determination of the mode were made in portions of the rock which contained more alkali feldspar and less biotite than

TABLE 2. GRANITES OF WASHINGTON, D. C.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SiO_2	67.46	69.19	69.33	66.68	71.92	71.66	72.57	99.43	93.38	96.16
Al_2O_3	14.22	14.88	14.33	14.93	13.24	13.97	15.11	0.11	3.09	1.31
Fe_2O_3	1.33	1.30	n. d.	1.58	1.82	1.34	1.02	0.21	0.72	0.02
FeO	3.24	2.64	3.60	3.32	2.01	1.92	0.59	0.12	n. d.	0.09
MgO	2.85	2.06	2.44	2.19	1.14	1.29	0.30	0.03	0.43	0.03
CaO	3.72	3.36	3.21	4.89	1.45	1.15	1.65	0.05	0.34	trace
Na_2O	2.88	3.28	2.70	2.65	3.81	3.40	3.92	0.03	0.50	0.56
K_2O	2.84	3.02	2.67	2.05	4.54	3.94	4.33	0.06	1.32	0.30
H_2O +	0.57	0.18	1.22	1.09	0.10	0.80	0.47	0.05	n. d.	0.51
H_2O —	0.12	0.09	——	0.16	0.08	0.33	——	0.02	n. d.	0.08
TiO_2	0.47	0.42	n. d.	0.50	0.36	0.79	n. d.	none	0.12	n. d.
ZrO_2	none	n. d.	n. d.	n. d.	none	n. d.	n. d.	n. d.	n. d.	n. d.
P_2O_5	0.31	0.14	0.10	0.10	0.23	0.14	n. d.	none	none	n. d.
S	0.02	n. d.	n. d.	n. d.	0.04	n. d.	n. d.	n. d.	n. d.	n. d.
MnO	0.08	0.12	n. d.	0.10	0.08	n. d.	n. d.	none	n. d.	n. d.
BaO	0.04	n. d.	n. d.	0.08	none	n. d.	n. d.	n. d.	n. d.	n. d.
	100.15	100.68	99.60	100.32	100.74	100.73	99.96	100.11	99.90	99.06

(1) Biotite granite, Tilden Street quarry. WASHINGTON analyst.
(2) Biotite granite, Newark Street quarry. WASHINGTON analyst.
(3) Biotite granite, Broad Branch Road quarry. PACKARD analyst. G. P. MERRILL. Bull. Geol. Soc. Amer. **6:** 321. 1895.
(4) Biotite granite, Rowlandsville, Maryland. HILLEBRAND analyst. G. H. WILLIAMS, U. S. Geol. Survey Ann. Rep. **15:** 672. 1895.
(5) Muscovite-biotite granite, River Road quarry. WASHINGTON analyst.
(6) Muscovite-biotite granite (foliated). Rodman Street opening, WASHINGTON analyst.
(7) Muscovite-biotite granite. Guilford, Maryland. HILLEBRAND analyst. C. R. KEYES, U. S. Geol. Survey Ann. Rep. **15:** 716. 1895.
(8) Quartz vein in granite, River Road quarry. WASHINGTON analyst.
(9) Northfieldite, Pelham, Massachusetts. E. T. ALLEN analyst. B. K. EMERSON, Amer. Journ. Sci. **40:** 215. 1915.
(10) Quartzose border of granite. A. R. DWERRYHOUSE analyst. DWERRYHOUSE, Quart. Journ. Geol. Soc. **65:** 64. 1909.

TABLE 3. NORMS OF BIOTITE GRANITE

	(1)	(2)	(4)
Quartz	26.46	27.06	28.26
Orthoclase	16.68	17.79	12.23
Albite	24.63	27.77	22.53
Anorthite	16.40	15.85	22.52
Corundum	0.30	0.41	none
Diopside	——	——	1.19
Hypersthene	11.32	8.63	8.90
Magnetite	1.86	1.86	2.32
Ilmenite	0.91	0.76	0.91
Apatite	0.67	0.34	0.34

(1) Tilden Street. Symbol (I)II.4."3.3(4).
(2) Newark Street. Symbol I(II).4.(2)3.3(4).
(4) Rowlandsville. Symbol (I)II."4.3."4.

the larger and more representative amount of material used for the analysis.

MUSCOVITE-BIOTITE GRANITE (RIVER ROAD TYPE)

A binary granite, containing about equal amounts of muscovite and biotite, occurs in and near Washington, but is less abundant than the biotite granite. Similar general quantitative relations between the types seem to hold good in the Maryland granites as described by Williams and Keyes, as well as in the granites of Georgia, as described by Watson.[6]

Megascopic characters.—The binary granite occurs in massive, unfoliated form, as at the River Road quarry of the Bethesda Blue Granite Company, about 1.3 km. northwest of the District line, in Maryland, which is being actively worked. The rock of this quarry may be regarded as typical. An intensely and finely foliated, gneissoid form was collected by Dr. M. Aurousseau of this Laboratory at a small opening on Connecticut Avenue, near the corner of Rodman Street. This last was thought by him to be a highly foliated portion of the granite exposed at Newark Street, about 0.3 kilometer to the south, but the exact relations are unknown.

The River Road granite is light gray and of finer grain than the Tilden Street type. Small plates of both muscovite and biotite are abundant; they are arranged in small, irregular streaks and patches, producing a slightly foliated structure. The Rodman Street specimen is darker gray, much finer grained, and with a highly foliated, gneissoid texture.

Microscopic characters.—In thin section the two are much alike, except for the distinctly foliated arrangement shown in sections of the Rodman Street granite cut across the foliation. The texture is highly cataclastic, both rocks giving evidence of intense crushing and some recrystallization. Irregular, fragmental granules of quartz and alkali feldspar are abundant, with few of finely twinned oligoclase. Irregular shreds of biotite, which is a decidedly greener brown than in the other type, and tables of primary muscovite, are common. The two micas are frequently intergrown, the muscovite being generally included in the biotite, and these larger crystals of muscovite are clearly primary. There is no amphibole nor magnetite, and small grains of epidote are very rarely seen. Small irregular areas composed of grains of quartz and highly crushed and sericitized

[6] T. L. WATSON, Amer. Geol. **27**: 199. 1901; Georgia Geol. Survey, Bull. 9-A. 1902.

orthoclase are rather common; the small plates of secondary muscovite in these show a tendency to a latticed arrangement. Rosiwal measurements on the sections of the River Road granite gave figures corresponding to 7.2 per cent of biotite and 7.4 per cent of muscovite by volume. The River Road granite resembles that of Guilford, Maryland, as described by Keyes.

Composition.—Chemical analyses were made of specimens both from the River Road quarry (5) and the Rodman Street opening (6), and the results are given in table 2, together with an analysis of the Guilford, Maryland, granite (7), described by Keyes.

The two Washington muscovite-biotite granites closely resemble each other, that of the River Road quarry being slightly higher in both alkalies, and with inverse proportions of magnesia and lime. In their general chemical characters, and in their modal details, they are very like the common granites of New England, Maryland, Virginia, South Carolina, and Georgia.[7] The Guilford granite is slightly higher in silica and alumina,[8] and lower in magnesia; it is probable that this has a higher content of muscovite than the Washington granites.

Norm.—The norms, shown in table 4, call for no special comment. As shown by the symbols the three granites fall in toscanose, the subrang to which belong more of the igneous rocks than to any other, and in which most of the Piedmont granites fall.

QUARTZOSE PHASES

The granite of the River Road quarry contains some small stringers and veinlets of a white, finely granular, highly quartzose aplite, with sharp boundaries between the veins and the granite. The microscope shows that this material is composed almost wholly of small, irregular, interlocking grains of quartz, with very few of orthoclase, and rare small muscovite flakes. The quartz and feldspar grains show slight undulatory extinction. The analysis (8) of the quartz aplite of one of these veinlets shows that it is almost pure quartz, with about one per cent of feldspar and mica. This quartz aplite closely resembles the northfieldite described by Emerson,[9] except that the latter is rather more coarse grained, contains more feldspar and mica, and is more decidedly pegmatitic. A highly

[7] Cf. *Chemical analyses of igneous rocks*, 1884–1913. U. S. Geol. Survey Prof. Paper 99: 167–175.

[8] The higher alumina is caused, in part, by the non-determination of titanium and phosphorus oxides.

[9] B. K. Emerson. Amer. Journ. Sci. 40: 212. 1915.

quartzose rock found by J. E. Spurr near Helvetia, Arizona, but as yet undescribed, also is closely similar.[10] This was provisionally named arizonite by Spurr and me, but Emerson's name, northfieldite, would seem to have priority. As pointed out by Emerson, as well as by Spurr in the manuscript of his paper, such rocks are to be considered as the ultra-silicic, hydrated portions of the magma, which were the last to solidify in shrinkage cracks of the still hot and recently solidified mass.

GENERAL RELATIONS

Although this paper aims only to present the results of several analyses of the granites of Washington, as a contribution to our scanty knowledge of the petrology of the District of Columbia, yet a few remarks may be permitted on the general relations of the igneous rocks. The published data are very few, and my personal acquaintance with the field geology is of the slightest. It would seem, however, that there is possibly an approach to regularity in the structural arrangement of the igneous rocks of the batholithic (?) intrusive mass.

Referring to the Historical Geology Sheet of Folio 70, we see that a broad band of "granite-gneiss" cuts obliquely across the western portion of the area. This has a mode much like that of the River

TABLE 4. NORMS OF MUSCOVITE-BIOTITE GRANITE

	(5)	(6)	(7)
Quartz	27.82	32.16	28.68
Orthoclase	26.69	23.35	25.58
Albite	31.96	28.82	33.01
Anorthite	5.28	5.00	8.34
Corundum	0.20	2.24	0.92
Hypersthene	4.75	4.26	2.12
Magnetite	2.32	1.86	0.93
Ilmenite	0.61	1.52	——
Apatite	0.67	0.34	——

(5) River Road quarry. Symbol I''.4.(1)2.3.
(6) Rodman Street opening. Symbol I''.(3)4.''2.3.
(7) Guilford, Maryland. Symbol I.4.2.3''.

Road binary granite, but the chemical analysis[11] of one specimen much resembles that of the biotite granite of Tilden Street. Toward the northern part of this gneiss (within the Washington quadrangle) are two long areas of biotite granite, with some muscovite-biotite

[10] An analysis of this is given in U. S. Geol. Survey Prof. Paper 99: 51.

[11] Cf. G. H. WILLIAMS, *op. cit.* p. 670; also U. S. Geol. Survey Bull. 591: 49. 1915.

granite. Whether these are part of the same intrusive complex as the granite-gneiss I am unable to say. In the northwestern corner of the sheet we meet with a broad band of diorite, as well as a narrow streak and what are apparently small outcrops cutting the Carolina gneiss along Scott's Run. Diorite is also met with in Georgetown and in the old tunnel of Rock Creek Park, analyses of which have been published.[12] A small exposure of "gabbro" occurs about 2 kilometers west of Bethesda, in the northwest part of the quadrangle. Few exposures of diorite and none of gabbro seem to have been found or recorded in the central granitic part of the igneous area. Thus, although the structural relations are apparently somewhat complex, and their study and interpretation in the field offer difficulties, as Keith points out, the distribution of the various kinds of igneous rock points to some magmatic differentiation in the intruded mass, in the sense that it is more silicic and salic near the center and more femic toward the borders. This is a mode of differentiational arrangement which is commonly met with, and which is so well known as not to call for the citation of corroborative examples here.

The available chemical evidence bears out this suggestion, in that the few analyses that have been made of the Washington igneous rocks show serial relations between them, indicating a community of origin. A very brief statement of this topic must suffice here.

The serial and comagmatic relations are shown most succinctly by the symbols denoting the positions of the various rocks in the quantitative classification, which, it is assumed, are intelligible to the reader. The analysis of the fresh Broad Branch granite given by Merrill is included. The series of rocks and symbols is given in table 5.

Inspection of these symbols shows clearly the gradual and progressive change in all the most essential chemical characters. As regards the relation of salic to femic molecules, the highly silicic binary granites are well within persalane, the less silicic biotite granites are all on the border between persalane and dosalane, and the diorites are in dosalane and salfemane. The amount of excess silica, shown in the ordinal positions, remains almost constantly quardofelic. There is a steady and almost uniformly regular decrease in alkalies as compared with salic lime as we go down the list, and a concomitant decrease in potash and increase in soda.

The same story is told by plotting the analytical data in the usual

[12] U. S. Geol. Survey Bull. 591: 47 (E and F).

way, using the molecular numbers as ordinates and the molecular silica percentages as abscissas; or still more clearly, by plotting the relative percentages of the basic oxides (alumina to potash) taken together against the silica percentages. The graphs for each constituent thus obtained show very regular decreases or increases, quite in accordance with such observations as have been made on rock series from other regions. The points thus indicated furnish curves that need scarcely any "smoothing out," with the exceptions of certain data for the Rodman Street granite and the Rock Creek Tunnel hornblende diorite, some of the figures for which fall quite markedly outside the smooth curves given by the others, indicating that they are aberrant for some reason, such as possibly assimilation of intruded gneiss.

SUMMARY

The igneous rocks of the District of Columbia are intruded into Archean gneisses. Granites are most abundant, with small amounts of diorite, gabbro, and pyroxenite.

There are two types of granite: biotite granite (which seems to be the more common), and muscovite-biotite granite. Both contain small amounts of oligoclase, but they differ chemically as well as regards the kind of mica present, the biotite granite being lower in silica and higher in lime. Transition forms probably occur. The biotite granite has silica percentages from 67.5 to 69.0 while that of the binary granite is about 72. Both types have undergone pressure, giving rise to more or less well marked foliated textures, although no very decided difference in chemical composition seems to be associated with the foliation. Epidote is developed in the more intensely crushed portions of the biotite granite, and this mineral is apparently wholly secondary in origin. Epidote is very rare or absent in the binary granite. No allanite, hornblende, or pyroxene was observed in the Washington granites.

TABLE 5. IGNEOUS ROCKS OF WASHINGTON, D. C., ARRANGED IN CHEMICAL SERIES

Name	Locality	Analysis and map reference	SiO_2	Symbol
Binary granite	River Road	(5)	71.92	I″.4.(1)2.3
Binary granite	Rodman Street	(6)	71.66	I″.(3)4.″2.3
Biotite granite	Broad Branch	(3)	69.33	(I)II.(3)4.3.3(4)
Biotite granite	Newark Street	(2)	69.19	I(II).4.(2)3.3(4)
Biotite granite	Tilden Street	(1)	67.46	(I)II.4.″3.3(4)
Biotite diorite	Georgetown		56.41	II″.4″.″4.4
Hornblende diorite	Rock Creek Tunnel		56.18	″III.4.4.4

The igneous rocks of the District have been but little studied, but there is reason to believe that the igneous complex is more femic toward the borders through magmatic differentiation. The analyses indicate a close comagmatic relationship between the various rocks. Further study of the igneous rocks of the District is very desirable.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. The abstracts should conform in length and general style to those appearing in this issue.

GEOLOGY.—*Geology of the igneous rocks of Essex County, Massachusetts.* CHARLES H. CLAPP. U. S. Geol. Survey Bull. **704.** Pp. 132. 1921.

Essex County is the northeasternmost county of Massachusetts. The special area whose geology is more particularly discussed in this bulletin lies almost wholly in the southern part of the county. Geologically the area is well known, chiefly because of its alkaline igneous rocks, among which are the types essexite and bostonite. Besides presenting local problems the area illustrates certain general features of the geology of igneous rocks, the more important of which are: (1) The sequence of the volcanic, batholithic, and dike phases of an igneous cycle. (2) The differentiation of two contrasted groups of rocks, the sub-alkaline, or calci-alkalic, and the alkaline. (3) The origin of shatter breccias along molar contacts of batholiths and the slope of molar contacts. (4) The contact assimilation of country rock by invading igneous magmas, forming hybrid rocks. (5) The formation of diabase dikes contemporaneously with irruptions of alkaline granitic rocks.

The writer throws light on some of the broader principles of the geology of igneous rocks, notably the formation of hybrid rocks by contact brecciation and assimilation and by impregnation of invaded rocks, and the differentiation of subalkaline magmas. The report discusses in detail the lithologic character, alteration, contact and structural relations of the considerable variety of igneous rocks found in the region. R. W. STONE.

GEOLOGY.—*Permian salt deposits of the south-central United States.* N. H. DARTON. U. S. Geol. Survey Bull. **715-M.** Pp. 19 (205 to 223), pl. 1 (21), figs. 10. 1921.

The bulletin presents a review of knowledge about the area of underground salt in eastern New Mexico, the Panhandle of Texas, and adjacent parts of Oklahoma and Kansas. A map shows the probable approximate extent of the area which is at least 650 miles long and 150 to 250 miles wide. Information about the salt beds is derived from drilling for oil, gas, and water, but the difficulty of recognizing salt when penetrated in the ordinary methods of drilling is pointed out. The salt succession undoubtedly occurs in the Permian beds known as the Manzano group in New Mexico and the Marian formation in Kansas associated with red beds, gypsum, anhydrite, dolomite, and limestone. The salt is not a continuous body, but probably composed of separate lenses and the sections in which it occurs in different places are not comparable in detail.

The deposit lies in a wide synclinal basin with minor folds. The thickest salt is approximately at the bottom of the basin. This basin may there-

fore have existed at the time the salt was deposited. The greatest thickness reported is 700 feet. Thicknesses of 200 to 400 feet are not uncommon. For several years commercial deposits of potash salts have been sought in this salt mass but so far without success. Verbal records and graphic logs of the principal wells penetrating the salt in this area are given for each State involved. The author believes that the salt was formed by the evaporation of sea water in shallow basins with occasional deeper marine submergences indicated by beds of [marine?] limestone.

MARCUS I. GOLDMAN.

GEOGRAPHY and HYDROLOGY.—*Routes to desert watering places in the Salton Sea region, California.* JOHN S. BROWN. U. S. Geol. Survey Water-Supply Paper **490-A.** Pp. 86, pls. 7, figs. 2. 1920.

This is the first of a series of detailed guidebooks on watering places in the desert region of the United States that is being prepared by the U. S. Geological Survey as authorized by Congress. The text comprises a brief description of the Salton Sea region—about 10,000 square miles in extent—practical suggestions to travelers, detailed logs of all desert roads with special reference to water supplies, and a list of watering places with brief descriptions. There is also a preface by O. E. MEINZER, which outlines the desert region of the United States (about 500,000 square miles in extent) and describes the scope and methods of the watering-place survey. The maps include a general map of the desert region of the United States and detailed relief maps of the Salton Sea region showing roads and watering places. The relief shading is by JOHN H. RENSHAWE. O. E. M.

PALEONTOLOGY.—Orthaulax, *a Tertiary guide fossil.* C. WYTHE COOKE. U. S. Geol. Survey Prof. Paper **129-B.** Pp. 15 (23–37), pls. 4 (2–5). 1921.

Had this paper been written even so late as five years ago, it might well have been entitled, "*Orthaulax*, a guide fossil of the Middle Oligocene." The more conservative caption is necessitated by recent discoveries in Santo

Known stratigraphic occurrence of Orthaulax.

Age.		Southeastern United States.	Dominican Republic.	Porto Rico and Jamaica.	Leeward Islands.	Cuba.	Panama.
Miocene.	Upper.	Yorktown and Duplin formations.	Cerros de Sal formation.				
	Middle	St. Marys formation.[a] Choptank formation.[a] Calvert formation.[a]	Mao clay. Mao Adentro limestone. Gurabo formation.	Bowden marl.		La Cruz marl.	Gatun formation.
	Lower.	Shoal River marl member. Oak Grove marl member. Chipola marl member *O. gabbi.* Alum Bluff formation.	Yaque group. *O. upadillensis* (exact position not known). Cercado formation Bulla formation. *O. burnetta.*			Marl at Baracoa.	
Oligocene.	Upper.	Tampa formation. *O. poyeti.* *O. burnetta.* Chattahoochee formation.	Cevicos limestone. *O. upadillensis.*	Aguadilla limestone. *O. upadillensis.*	Anguilla formation and limestone in St. Croix. *O. upadillensis.*	Limestone at Constalacion del Sur (position doubtful). *O. ocapa.*	Emperador limestone. *O. gabbi.*
	Middle.	Chert beds on Flint River, Ga. *O. poyeti.*	Tabera formation.		Antigua formation. *O. poyeti.*		*O. gabbi.* Culebra formation.
	Lower.	Vicksburg group.					

[a] Faunal evidence is unsatisfactory, according to T. W. Vaughan, that these formations classed by him in previous reports as Tortonian (upper Miocene), are of Helvetian (middle Miocene) age. This is a return to the opinion stated by Dall in 1898.

Domingo and by the downward trend of the arbitrary line dividing the Miocene from the Oligocene. The article is concerned with the value of *Orthaulax* as a *leit* fossil, the biological peculiarities of the genus, the historical development of the knowledge about it, the distribution of the known species and the systematic treatment of the five forms referred to it.

Orthaulax is unique among the gastropods in that the entire spire is encased in a shelly envelope, a modification of the outer lip analogous to the finger growths and flanges upon the closely related stromb, the common conch of the West Indies. As in most highly specialized groups, the term of life is short, and, even with the increased knowledge, the limits of distribution remain comparatively narrow. The tabular occurrence of the genus indicates its importance stratigraphically.

The systematic treatment is remarkable for the refinement of method employed. The determination of the species is based finally upon the sectioning of the specimens, though the characteristics are, as a rule, sufficiently distinct to justify a confident field determination.

JULIA GARDNER.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

WASHINGTON ACADEMY OF SCIENCES

153D MEETING

The 153d meeting of the ACADEMY was held jointly with the Chemical Society of Washington in the assembly hall of the Cosmos Club, the evening of Thursday, January 20, 1921. The retiring President of the Academy, DR. C. L. ALSBERG, Chief of the Bureau of Chemistry, U. S. Department of Agriculture, delivered an address entitled *The relation of chemical structure to physiological action*. This has subsequently been published in the JOURNAL of the ACADEMY.[1]

154TH MEETING

The 154th meeting of the ACADEMY was held at the Cosmos Club, the evening of Thursday, February 17, 1921. Dr. L. O. HOWARD, Chief of the Bureau of Entomology, U. S. Department of Agriculture, delivered an illustrated lecture entitled, *How the Government is fighting insects*. He discussed briefly the work of the Bureau over which he has presided for the last 27 years and with which he has been connected for more than 40 years, and traced the extraordinary growth of the service, which has been due to the increasing realization of the monetary importance of remedial work against insects affecting crops, the health of man and animals, stored food, and so on. From a beginning with one entomologist and an assistant, the Bureau has grown to a large organization with a budget of nearly two million dollars, with field laboratories scattered all over the country to the number of 75 or more, and with a corps of trained expert assistants numbering several hundreds.

Lantern slides were shown of the operations being carried on at a number of these stations against some of the principal crop pests, and the lecture closed with a moving picture film showing the latest discoveries in the fight against the cotton boll weevil.

In the course of his talk the speaker emphasized the point that the greater part of the work carried on in the Bureau is of the highest scientific character, requiring men of intensive training.

[1] This JOURNAL **11**: 321–341. August 19, 1921.

155TH MEETING

The 155th meeting of the ACADEMY was held at the Cosmos Club, the evening of Thursday, March 17, 1921. Dr. A. McL. NICOLSON, research engineer of the Western Electric Company, Inc., New York, delivered an address on *The piezo-electric effect in certain crystals*. The address was illustrated with lantern slides, and demonstrations were given of some of the practical applications of the crystals to the transmission and reception of sound.

156TH MEETING

The 156th meeting of the ACADEMY was held jointly with the Biological Society of Washington at the Cosmos Club, the evening of Saturday, April 2, 1921. Dr. A. D. HOPKINS of the Bureau of Entomology, U. S. Department of Agriculture, delivered an address entitled *Intercontinental problems in natural and artificial distribution of plants and animals*. In condensed form this has since been published in two papers in the Journal of the Academy: (1) *Intercontinental problems in bioclimatics; with special reference to natural and artificial distribution of plants and animals.*[2] (2) *Bioclimatic zones of the continents; with proposed designations and classification.*[3]

157TH MEETING

The 157th meeting of the Academy was held at the Cosmos Club the evening of Thursday, April 21, 1921. Dr. C. G. ABBOT, Assistant Secretary of the Smithsonian Institution, delivered an address on *The solar constant observing stations of the Smithsonian Institution*.

In the course of his lecture the speaker described the studies of solar radiation carried out at Washington, D. C.; Bassour, Algeria; Hump Mountain, North Carolina; Mount Harqua Hala, Arizona; Mount Wilson, California; Calama, Chile; Montezuma, Chile; and Mount Whitney, California, at altitudes ranging from sea level to 14,500 feet. He summarized results accomplished in perfecting processes of investigation, in the invention and construction of highly precise standardized instruments, and in the securing of simultaneous determinations of the solar constant of radiation at Washington, Mount Wilson, and Mount Whitney; and the bearing of these results, notably with respect to meteorological investigations. The data are brought together in a paper of 20 printed pages, entitled *Studying the sun's heat on mountain peaks in desert lands*, which will appear shortly in the Appendix to the Report of the Smithsonian Institution for 1920.

WILLIAM R. MAXON, *Recording Secretary*.

BOTANICAL SOCIETY

150TH MEETING

The 150th regular meeting of the Botanical Society of Washington was held in the Assembly Hall of the Cosmos Club at 8 p.m., Tuesday, March 1, 1921. 112 members and guests were present. Among the visitors were Dr. ROBERT F. GRIGGS of Ohio, Prof. LEO E. Melchers of Kansas, Dr. A. G. JOHNSON of Wisconsin, Mr. PAUL SIGGERS, about to leave for his new work with Johnston and Carleton in Panama, and Mr. C. VALLEJO, Agricultural Attaché of the Argentine Republic. In the absence of President CHAMBLISS, the meeting was called to order by Vice-President P. L. RICKER.

[2] This JOURNAL 11: 223–227. 1921.

[3] This JOURNAL 11: 227–229. 1921.

A preliminary report was made by Dr. A. S. HITCHCOCK on the question of providing Russian men of science with scientific literature.

Regular Program

HAVEN METCALF: *The story of a plant introduction.* (Address of the retiring President, illustrated with lantern slides.)

Because of various diseases and other factors, rice culture in the South Atlantic States was on the decline in the early nineteen hundreds. One rice disease in South Carolina called "blast" or "rotten-neck" was very serious. In order to study the disease further, Dr. and Mrs. Metcalf took a trip to Italy and found that the "Brusone" was the same as blast in South Carolina. Resistant rices were secured and introduced into the United States. They did not retain their resistance, but one of them, now known as Colusa, by still further selection, has become the second in production in California, producing in 1919 1,655,000 bushels of grain, with an estimated farm value of over four million dollars. (A fuller discussion of Dr. Metcalf's address will be published elsewhere.)

ROY G. PIERCE, *Recording Secretary.*

151ST MEETING

The 151st regular meeting of the Society was held in the Assembly Hall of the Cosmos Club at 8:00 p.m. Tuesday, April 5, 1921. 51 members and guests were present. President CHARLES E. CHAMBLISS presided. Mr. SOREN SORENSON and Mr. D. RUDOLF KURAZ were elected to membership. Mr. P. L. RICKER reported on the work of the committee on the preservation of the Shaw water lily garden. A contribution from the Botanical Society toward the printing of a pamphlet and map in furtherance of the project was requested, and was authorized. Mr. RICKER announced a series of "hikes" conducted by the Wild Flower Preservation Society and invited the members to join them.

Regular Program

W. H. WESTON: *Following a fungus through the Philippines.*

This lecture was illustrated with lantern slides exhibiting various phases of the botany of the islands, particularly the terraced rice fields, the tropical jungles, and the conditions surrounding the development and spread of the downy mildew of maize.

All but one of the known species of the downy mildews of corn occur in the Orient. No conception of the terrifically destructive effect of this disease can be gained from comparison with any disease known in America. Whole fields are destroyed. The disease is carried through the season by the production of enormous numbers of conidia. *Saccharum spontaneum,* wild grass, *Miscanthus japonicus,* and a primitive type of cultivated sugar cane growing in the remote interior of Northern Luzon were also found to be hosts of this disease. Maize of flinty, poor yielding, tropical types was found to be grown under widely varying conditions, ranging from the swampy soil and coral sand of the hot, humid coast, to the precipitous rocky slopes of high elevations in the cooler mountainous interior. Waxy maize, hitherto known only from China and Burma, was collected from two widely separated localities. On all these types the mildew was, under favorable conditions, almost equally destructive, its ravages, which were aided greatly by the

primitive agricultural practices of the people, being largely instrumental in bringing about such serious local food shortages as that which recently caused great hardship in Bohol.

J. F. CLEVENGER: Zamia integrifolia *Chapm., and its starch, Florida arrowroot.* (Illustrated with lantern slides).

Zamia integrifolia Chapm. is a small plant with a crown of leaves characteristic of the Cycadaceae, to which family this plant belongs. It has an enlarged tuberous-like stem which grows below the level of the ground. It is of interest that numerous prominent root tubercles occur on the roots of this plant. It is restricted to a limited region in the vicinity of Miami, Florida. It has not been found very far south of Miami and not much north of Dania, Florida, nor in regions which are liable to overflow.

Gifford reports "that in its raw state the leaves, seed and stems are undoubtedly poisonous." He further states "that animals which drink the red water from washing the starch usually die of slow poisoning." There are no available statements relative to the nature of this poison.

The starch has been prepared by the Seminole Indians and natives of South Florida by rather crude mills. The starch thus obtained constitutes an important source of food. For some time there existed in southern Florida two mills of comparatively large capacity, one at Dania and one at Little River. At the present time only the mill at Little River is engaged in the manufacturing of this starch.

The method for the preparation of this starch consists in grinding the rhizomes in the undried condition, mixing the ground material thus obtained with water, and subsequently running it over a fine screen. The starch is thus separated from the main portion of the fibrous material. This starchy material is then conveyed to settling tanks where the starch becomes further purified by a sedimentation process. This starch is subsequently dried and ready for the market.

It is believed to have been used by the natives who preceded the Seminoles, as a source of food. It supplied the early settlers with food, and to some extent, at least, enters into the arrowroot biscuit of commerce. It is interesting to point out that the people frequently dig up these rhizomes, soak them in water, and subsequently use them for fertilizer. The plant has been used as a pot plant, by transplanting.

Judging from the rapidly diminishing areas over which this plant grows, the apparent improbability of growing the plant profitably on new areas, and the long periods of waiting before the rhizomes from any given region may be subsequently dug up with profit, it is improbable that the starch will ever have anything more than a limited use.

The paper of Mr. ARNO VIEHOEVER was postponed to the 152d regular meeting.

R. KENT BEATTIE, *Acting Secretary.*

SCIENTIFIC NOTES AND NEWS

The Section of Vertebrate Paleontology of the U. S. National Museum has recently received as a gift from the John A. Savage Company of Crosby, Minnesota, an extensive collection of bones of an extinct buffalo, named *Bison occidentalis* some years ago by Dr. F. A. LUCAS. These remains were discovered in Pleistocene deposits which overlie a body of iron ore at the Sagamore Mine near Riverton, Minnesota. It has been comparatively easy to select a complete composite skeleton, which it is proposed to mount for the exhibition collection.

Secretary of Agriculture WALLACE has appointed a committee of six scientists from the Department to consider the problem of land utilization. The committee consists of Messrs. L. C. GRAY of the Office of Farm Management and Farm Economics, C. V. PIPER of the Bureau of Plant Industry, G. M. ROMMEL of the Bureau of Animal Industry, C. F. MARBUT of the Bureau of Soils, E. E. CARTER of the Forest Service, and S. H. MCCORY of the Bureau of Public Roads.

The Bureau of Standards announces that in testing a number of imported sets of analytical weights it has been found that the weights from 500 to 50 mg. were made of a decidedly magnetic material. This property caused them to behave very irregularly under test. Such weights can readily be detected with a small hand magnet, and it would be well for purchasers of analytical weights to be on their guard against them, as under some circumstances serious errors might be introduced thereby.

Dr. C. G. ABBOT of the Astrophysical Observatory sailed from New York on October 26 for Antofagasta, Chile, to inspect the solar radiation station at Mt. Montezuma. He expects to return in January.

Dr. L. H. DUDLEY BUXTON, anthropologist, visited the scientific institutions of Washington in October, on his way around the world on the Kahn traveling fellowship from Oxford University, England.

Dr. IMMANUEL FRIEDLÄNDER, Director of the Volcanological Institute of Naples, visited the Geophysical Laboratory and the U. S. Geological Survey in October.

Mr. JAMES E. IVES has resigned as research associate and lecturer in physics at Clark University to become physicist in the office of industrial hygiene and sanitation of the Public Health Service in Washington.

Dr. WILLIAM C. KENDALL, scientific assistant and ichthyologist of the U. S. Bureau of Fisheries, has resigned after 33 years of service with the Bureau, to accept the position of ichthyologist in the Roosevelt Wild Life Forest Experiment Station of the New York State College of Forestry, Syracuse, New York.

Mr. GEORGE M. ROMMEL, chief of the animal husbandry division of the Bureau of Animal Industry, U. S. Department of Agriculture, has resigned to become editor-in-chief of the American International Publishers, New York City. Mr. Rommel had been with the Department since 1901, and had been chief of his division since its organization in 1910.

Dr. RALPH W. G. WYCKOFF, of the Geophysical Laboratory, Carnegie Institution of Washington, is on a year's leave of absence, which he will spend at the California Institute of Technology at Pasadena, California.